Evaluating the Potential for Improvements to Habitat Condition to Improve Population Status for Eight Salmon and Steelhead ESUs in the Columbia Basin

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INTRODUCTION

Objective and Task Description

In this paper, we present analyses in support of the 2004 FCRPS Biological Opinion Remand effort, aimed primarily at answering the question*: Is there potential to improve anadromous salmonid population status through improvements to habitat conditions in tributary or estuarine environments?* These analyses are intended to inform assessments of the potential for habitat improvements to effect positive change in salmon and steelhead population status.

Salmonid spawning and rearing habitat in the Columbia Basin has been affected by a variety of impacts (NRC 1996), and previous work has identified the theoretical potential for increases in early life stage survival to improve population status (Kareiva et al. 2000). However, impacts to habitat vary from location to location across the basin (McHugh et al. 2004), potentially complicating the use of habitat actions for widespread population status improvement. Here we assess the likelihood that changes to habitat can positively affect population status for eight ESUs considered substantially affected by the FCRPS hydropower system in the 2000 FCRPS Biological Opinion (NMFS 2000): Snake River spring/summer chinook (threatened), Upper Columbia spring chinook (endangered), Snake River fall chinook (threatened), Snake River steelhead (threatened), Upper Columbia steelhead (endangered), Mid-Columbia steelhead (threatened), Snake River sockeye (endangered), and Columbia River chum (threatened).

Approach to the analysis

To address this question, we conducted a series of analyses. First, we used Leslie matrix models and a brief literature review to ask the question: is it reasonable to hypothesize that increases in freshwater and estuarine survival can produce survival changes required to compensate for the impacts of the FCRPS hydropower system? Next, we identified tributary habitats with likely impairments to habitat-forming processes. Then, we characterized estuarine habitat conditions with respect to the likelihood that current conditions negatively affect different life history strategies. Finally, we evaluated current population status in comparison to historical population status for four characteristics important for long-term viability: abundance, productivity, spatial structure and diversity (McElhany et al. 2000). Because historical population characteristics are almost universally unknown, we estimated the "intrinsic potential" of the landscape to support chinook and steelhead, and used the results of this analysis as our hypothesis of historical population distribution.

After completing these analyses, we then categorized populations with respect to the degree and type of habitat problems identified and overall population status. In particular, we identified areas with minimal habitat or population status disruption – these areas may be important areas to maintain or protect. We also identified areas with extremely compromised habitat and poor population status – these situations are the areas where there is the greatest likelihood that habitat factors have negatively affected population status. However, necessary improvements to see changes in these fish populations may be substantial. Areas with moderately or minimally compromised habitat and poor population status may provide opportunities to improve population status with less effort, although these should be evaluated on a case-by-case basis to determine the likelihood that factors identified as impaired are strongly affecting survival or other population characteristics.

Scope of and Limits to the Evaluation

Our analysis is large-scale, encompassing all listed ESUs in the interior Columbia basin as well as Columbia River chum. This large focus brings with it several important considerations for each aspect of our evaluation.

First, our tributary habitat analyses are based largely on land use, and are aimed at identifying likely impairments or disruptions to natural landscape processes that appear to affect in-stream habitat conditions. Thus, they do not provide a detailed, local inventory of problems, or identify particular actions that should be taken in specific stream reaches. Rather, they indicate general areas where particular problems are likely (Beechie et al. 2003a).

Second, because our tributary habitat analyses are based on data widely available throughout the basin, the range of potential impacts we investigated was limited to sedimentation, riparian and floodplain corridor alterations, water quality (restricted to pesticide and herbicide applications), changes to in-stream flows, potential for entrainment in irrigation diversions, and barriers to passage. We do not address other factors, including (but clearly not limited to) exotic species, impacts of mining (either in-stream habitat alteration or water quality impacts), or nutrient cycling and availability. Local information about these additional impacts is clearly relevant and important for conservation planning efforts.

Similarly, our estuarine-habitat analysis examines a relatively limited number of potential impacts: flow, shallow-water habitat loss, toxics and tern predation. In addition, we do not provide population-specific evaluations of these impacts. Rather, our assessment of these impacts considers their importance to the life stages using the estuarine environments. ESUs are classified by their dominant life history strategy and how they use the estuary. We thus provide a general picture of the potential of key estuarine factors to affect population status for each ESU; as with our tributary analysis, additional factors we did not consider explicitly may also be relevant.

Finally, our assessment of the potential for the abundance, productivity, spatial structure or diversity of a population to improve is conducted by comparing current salmon and steelhead population status with a hypothesized historical distribution of those populations. A judgment that a population's status can improve for each of these metrics is independent of viability criteria currently being developed by the TRTs for the Interior Columbia (interior ESUs) and Lower Columbia/Willamette (Columbia River chum). It is instead an indication that a population's current status is substantially lower than it was historically, and could thus be improved.

Importantly, in spite of these considerations, our analysis does provide a consistent, population-level assessment of tributary and estuarine habitat factors generally thought to affect the health of salmon and steelhead populations. As such, it is a critical step in evaluating the likelihood that off-site mitigation actions aimed at habitat improvement have the potential to positively affect population health.

OVERVIEW OF METHODS

Life-cycle Modeling

We used Leslie-matrix models (Caswell 2000) to assess the sensitivity of interior Columbia ESUs to changes in survival in the freshwater and estuarine life stages. We constructed stochastic matrices for Snake River spring/summer chinook and Snake River steelhead. These stochastic matrices include considerations of ocean (climatic) conditions and density-dependence in the egg-parr stage. All subsequent mortality (parr-smolt, adult ocean survival, etc.) in this model structure is considered to be density-independent. Data to parameterize a stochastic matrix were not available for other ESUs, so we adapted previously developed deterministic, density-independent matrices for Upper Columbia chinook, Upper Columbia steelhead (Cooney et al. 2002) and Snake River Fall Chinook (CRI 2000). Importantly, each of these matrices is constructed at the ESU-level, rather than the population-level and thus is not specific to any particular population. We use these matrices to indicate general patterns of response rather than predict specific population-level responses to any identified action. We did not construct matrices for Columbia River chum, Mid-Columbia steelhead or Snake River sockeye because data were not available to parameterize models for these ESUs. Details of this analysis are included in Appendix A.

Using these models we evaluated the response of the ESUs to changes in freshwater survival (the Beverton-Holt productivity term, for those ESUs with stochastic matrices), freshwater capacity (for those ESUs with stochastic matrices), or estuarine/early ocean survival. We used three different response metrics: probability of falling below a threshold (analogous to extinction risk estimation); total number of spawners; and percent change in annual population growth rate. These different metrics allow us to gauge the population response in several ways, and thus provide a more complete picture of estimated changes to population status.

Finally, because data linking specific impacts or actions to changes in survival or capacity do not exist, we conducted a literature review for chinook salmon and steelhead lifestage-specific survival rates for comparison with modeled survival rates.

Tributary Habitat

Our basin-wide analysis of tributary habitat factor impairment includes an assessment of riparian and floodplain functions, erosion/sedimentation potential, in-stream flow regime, diversion entrainment, water quality and barriers to passage (in tributaries). These analyses are all GIS-based, and incorporated a range of information, from regional land-use/land-cover data to more local (generally statewide) information. They are intended to identify impairment to habitat-forming processes that influence in-stream habitat conditions. However, while each analysis is aimed at a particular process, additional impacts may be associated with these factors. In addition, each of these analyses is based on current land-use and data. Impacts that occurred in the past but that have been altered currently will not be indicated in these analyses.

Riparian and floodplain functions. . Riparian areas provide many functions that contribute to habitat that is suitable for viability of salmonids, as well as the integrity of the stream network itself (e.g., temperature control, filtering capacity, large woody debris recruitment, bank stability) (Meehan 1991). Connectivity of the stream and its floodplain provide necessary functions as well (Ward et al. 2002). This analysis is divided into two parts: first, an evaluation of stream-side buffer widths across different land use types using aerial photographs, and second, determining the proportion of streams falling within each land-use type. Two separate analyses were conducted: one aimed at floodplain areas, as determined by FEMA floodplain maps, and a second aimed at riparian areas not classified as floodplains. Impairments to normal temperature regimes may be associated with impairment or alteration to natural riparian functions.

Surface erosion on non-forested lands. Erosion on non-forested lands of the Columbia River basin is dominated by surface erosion and gullying processes, with relatively little contribution from mass wasting. Spatial variation in surface erosion rate is governed by several natural factors including hillslope angle, soil erosivity, rainfall intensity, and vegetation cover (Dunne and Leopold 1978). Agricultural practices typically increase surface erosion by reducing vegetation cover and exposing more of the soil surface to rainfall impact and overland flow. We calculated an index of change in surface erosion rate for each population using current and reference land-use and land cover information, based on the Revised Universal Soil Loss Equation (Renard et al. 1997).

Mass wasting and surface erosion on forested lands. A substantial literature concerning effects of forest practices (e.g., logging and road building) on mass wasting processes has established that clear-cut logging and road building significantly alter sediment supply rates from landsliding (Meehan 1991). In general, sediment supply rates increase by an order of magnitude with logging, and another order of magnitude with road building, as compared to natural areas. Increased sediment supply rates due to roads are similar east and west of the Cascades, but increased rates caused by clearcuts may be higher east of the Cascades. Further, intense stand-replacing fires can dramatically increases erosion rates in forested areas of the Columbia basin (Megahan et al. 1995, Meyer et al. 2001), and much of that increase is due to elevated rates of mass wasting. We summarized an estimated difference between current and reference condition sediment supply for each population using road density, timber harvest rates and land-use and land cover information.

In-stream flow regime. Water withdrawals in the Columbia River basin substantially alter stream flows experienced by many salmon populations. Available data indicate that most diversions in the Columbia River basin are for irrigation (Quigley and Arbelbide 1997), although it is currently not clear how much water is removed from streams. Data limitations include incomplete accounting of all diversions, withdrawals are not measured at each diversion, and return flows are difficult to account for. We used a database we compiled from several sources to estimate the potential proportion of water diverted (legal flow allocated within the population and in flow-providing areas upstream divided by mean flow during low flow periods) per population. Due to the data limitations associated with this factor, it is important to recognize that this metric is an index of potential impairment rather than an absolute measure. A high proportion of water potentially diverted may also be associated with relatively higher stream temperatures.

Diversion entrainment. In addition to altering in-stream flows, diversions have the potential to entrain outmigrating smolts in irrigation canals, thereby affecting survival of those outmigrating smolts. Data limitations, as with in-stream flows, include incomplete accounting of all diversions, withdrawals not measured at each diversion, and a lack of information about the presence or status of screen on any diversions. We therefore treat the number of diversions each population encounters as a relative measure of the impact of entrainment on the population. We calculated the number of diversions within the population boundary and on its downstream migration path. In addition, we estimated the proportion of the stream flow diverted at each intake/diversion, based on the legally allotted flow for that diversion, since the potential for entrainment varies with the proportion of water removed from the stream (Neeley 2000). While this analysis was aimed at identifying locations with a high potential for entrainment, these areas (high in the number of diversions) may also be associated with stream reaches likely to be channelized.

Water Quality (Pesticide). Pesticides are frequently detected in salmon habitat throughout the Columbia Basin. For example, 50 different pesticides were recently detected by the U.S. Geological Survey in the Willamette basin (Wentz et al. 1998), and 43 different pesticides have been detected in the lower Yakima River (Rinella et al. 1999). Sub-lethal effects of these pesticides on salmon survival and reproductive health are largely unknown, especially when they enter streams in complex mixtures. Trace metals and petroleum-based products also enter surface waters in high concentrations in urban areas (Wentz et al. 1998), and their effects on salmon are also poorly understood. Recent studies indicate that at least some of these compounds dramatically alter olfactory-mediated behaviors in salmon (Scholz et al. 2000), which can result in increased mortality during juvenile life stages. The potential for increased mortality combined with high exposure potential creates a critical uncertainty in our ability to identify actions necessary to improve population status. We calculated an index of likely exposure to pesticides based on land-use patterns and associated pesticide use.

Barriers. Many anthropogenic barriers, including culverts and diversion dams have blocked passage to previously accessible habitats either completely or partially. The states of Oregon, Washington and Idaho have begun inventories of these barriers. Unfortunately, however, it is frequently unknown whether a particular barrier blocks access completely. We calculated the proportion of historically available stream km that are currently inaccessible under two scenarios: first, assuming that only barriers known to be complete barriers blocked passage, and second, a worst-case scenario, assuming that all barriers categorized as "unknown" for degree of passage were complete barriers. We calculated stream km both as an absolute measure, and weighted by historical habitat quality. Note that this analysis was particularly plagued by lack of specific, local information. We are currently engaged in a comparison of the statewide databases and more detailed, local information provided to us by several subbasin assessment groups. Because of these data issues, we do not include barriers as one of the potential "impairments," but do identify those populations for which a substantial portion of historically available areas appear to be blocked.

For each of these analyses, we calculated the range of divergence from reference conditions across all populations within a species. Scientific research to date does not support the identification of a cutoff below which impacts from any of these factors to affected populations is minimal. Therefore, we divided the range of values for each factor into ten equal bins and ranked each population according to which bin it fell in for each factor. This binning allowed us to characterize the relative degree of divergence from reference conditions between populations. Because of the range of conditions present in the basin (from designated wilderness areas to highly altered landscapes), we assume that the range within each factor is associated with the likelihood that the factor has the potential to affect population status.

More detailed methods, data sources and descriptions for each of these tributary habitat analyses can be found in Appendix B.

Estuary Habitat

We relied on available scientific information to characterize changes in estuarine and plume conditions for four factors: flow, shallow-water habitat availability, toxics and tern predation. For each factor, we synthesized available information from the scientific literature and agency reports. We then generated a relative ranking of the impact of each factor on stream-type ESUs and ocean-type ESUs separately (Appendix C).

Population Status Assessment

We compared historical and current population abundance, productivity, spatial structure and diversity to determine whether values of each of these parameters had declined substantially, indicating that there is the potential to improve population status. Obviously, historical conditions are unavailable in virtually every case. We therefore estimated the intrinsic potential of the landscape to support salmon and steelhead, and used the results of this analysis as our hypothesis of the distribution of salmon and steelhead historically. This comparison does not consider whether current conditions or some point in between current and historical conditions could be considered viable, but rather only whether it is possible to increase the values of each of these parameters, assuming that historical values were a maximum potential.

Estimating historical distribution. Because the historical distribution of salmon and steelhead is known only generally, we generated a hypothesis of the historical distribution of stream-type chinook and steelhead using landscape features. Specifically, we rated each 200m stream segment in the interior Columbia basin as high, moderate or low in its intrinsic suitability for spawning (i.e. before anthropogenic impacts). Factors considered in this analysis included stream gradient, stream width, valley width and (historical) vegetation type, with specific ratings tailored to stream-type chinook and steelhead. (See Appendix D). This method of estimating intrinsic potential is consistent with analyses estimating potential capacity conducted by the Puget Sound and Lower Columbia/Upper Willamette TRTs. For chum salmon, we used a similar analysis conducted by the Lower Columbia/Upper Willamette TRT (Steel and Sheer 2002). Our Snake River Fall chinook historical distribution (for comparison with current) is based on historical accounts (Evermann 1896).

We recognize that this analysis cannot provide a perfect picture of historical distributions, since local factors other than these landscape features may influence local suitability. It is intended rather, to provide a general picture of salmon and steelhead distributions before European contact.

Current distributions. We used GIS layers available on Streamnet and refined with layers provided by Idaho Fish and Game, Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife to describe current spawning and rearing distribution. In a small number of cases, we have discovered errors in these data layers.

For consistency, however, we are using these layers as they were provided (i.e. we have made no changes), and are noting those errors.

We took the following approach to comparing historical and current population status for each viability-related parameter:

Abundance/Capacity. We evaluated two characteristics of abundance and capacity. First, for those populations for which a total population estimate was available, we calculated the geometric mean number of spawners for the last five years of the time series. The conservation literature suggests that a population size less than 500 is subject to a variety of demographic and genetic impacts severely limiting viability (Franklin 1980, Soule 1980, Soule and Gilpin 1986, Lynch 1990, Lande 1995). Therefore, we judged that any population with less than 500 spawners (geometric mean over five years) had potential for improvement with respect to abundance. For all populations, we also calculated a capacity metric, based on our intrinsic potential analysis (see Appendix E). If the value of this relative metric currently was 70% or less of the value historically, we considered the population to have potential for improvement with respect to capacity.

Productivity. To evaluate current productivity, we used four metrics used by the Biological Review Teams (BRT) during the 2002/2003 status reviews: short-term trend, long-term trend, long-term population growth rate, assuming hatchery fish do not contribute to subsequent generations and long-term population growth rate assuming that hatchery fish do contribute to subsequent generations (see Appendix E). Because it is essentially impossible to gauge a population's historical productivity, we judged that a population had potential to improve with respect to productivity if any one of these metrics was less than one (i.e. the trend or growth rate was declining). For many populations, data were not available to calculate productivity metrics. In these cases, we noted the lack of data; for categorization purposes, we assumed the average of each productivity metric across populations within the relevant ESU. The mean population growth rate of a group of populations is a robust indicator of the central tendency of that group (Holmes and Fagan 2002).

Spatial Structure. We used three metrics to gauge whether there was potential for a population's spatial structure to be improved. First, we calculated the percent of the potentially suitable habitat that is currently occupied; any value less than 66% was deemed as impaired (having potential for improvement). Second, we calculated the distribution of distances between 6^{th}-field HUCs with current or potential (historical) spawning and determined whether there was a significant difference between the historical and current distribution. Any significant difference was deemed to be impaired. Finally, we examined the range of distances between spawning areas; any substantial reduction in this range was judged to provide potential for improvement (see Appendix E). A population was deemed to have potential for improvement if any one of these conditions was met.

Diversity. Because relevant life history, genetic and morphological diversity has not been characterized for most populations, we relied on habitat differences, characterized by EPA-defined eco-region as a proxy for the potential for a population to express relevant diversity. We devised a diversity metric that considered both the number of eco-regions and the distribution across those eco-regions (see Appendix E). If the historical value was greater than the current value of this metric, we considered there to be room for the population to improve with respect to diversity. EPA eco-regions may be limited in their utility for describing aquatic community diversity. However, eco-region is associated significantly with factors thought to be important for salmonid life history diversity (including temperature, elevation and rainfall) (Morita, McClure and Spruell in prep.) For this exercise, eco-region was the only existent descriptor of habitat that was consistently available across the interior Columbia. We are currently investigating alternative diversity metrics.

Appendix E contains further details of our current status assessment.

RESULTS OVERVIEW

Life-Cycle Modeling

Snake River spring/summer chinook. We tested the sensitivity of model results to increases in estuarine/early ocean survival, the productivity term (slope) of the Beverton-Holt relationship and the "ceiling" of the Beverton-Holt relationship. Each response metric (spawner abundance, percent change in population growth rate and probability of falling below a threshold) changed most substantially to increases in estuarine/early ocean survival and to a joint increase in the slope and ceiling of the Beverton-Holt relationship. Changes to the slope of the B-H relationship alone produced the smallest responses (Fig. 1). Changes to parr-smolt survival, because it occurs after the imposition of density-dependence would generate a response similar to that of the estuarine/early ocean survival. This suggests that actions that increase survival during density-independent life-stages, or that increase the capacity of the system together with survival have the greatest potential to effect changes to the population status.

It is important to note however, that it is currently impossible to separate the mortality occurring in the estuary from mortality occurring in the near-shore or early ocean. Thus, the ability of conservation actions in the estuary to achieve predicted responses to increases in the estuarine/early ocean survival may be limited. If little of the mortality in this life stage occurs in the estuary, improved estuarine survival will have a much lesser impact on population growth rate and other response metrics (see Appendix A).

Snake River steelhead. Results for Snake River steelhead were qualitatively similar to those for Snake River spring/summer chinook salmon. However, increases in the Beverton-Holt ceiling produced a larger relative response for this species than for the stream-type chinook.

Upper Columbia River spring chinook, Upper Columbia River steelhead and Snake River fall chinook. Because we were only able to construct deterministic matrices for these ESUs, we were only able to use changes in population growth rate as a population performance metric. For all three ESUs, annual population growth rate is highly and identically responsive to increases in freshwater or estuarine/early ocean survival rates. In all three cases, a 50 percent increase in either first-year or estuarine/early ocean survival produced a 10-12 percent increase in population growth rate (see Appendix A). Again, realized responses to conservation actions, particularly in the estuary, will be dependent upon the proportion of mortality that can be affected by human actions.

Literature review: observed survival rates. We compiled observed freshwater survival rates for stream-type chinook salmon and steelhead from the published literature and agency reports. For chinook, available data allowed us to restrict our review largely to studies in the Columbia River Basin; these do include some hatchery studies. Steelhead data, include primarily hatchery fish due to the dearth of studies on wild fish; most studies are outside the Columbia. Observed egg-smolt (freshwater residence) survival rates within the Columbia River Basin ranged from as low as 0.02% up to 19.6%. Few studies investigated steelhead egg-smolt (freshwater residence) survival rates; observed values ranged from 0.28% to 1.6% (Table 1). None of these values were in the Columbia River Basin. Unfortunately, empirical observations of estuarine and early ocean survival rates for chinook and steelhead are not available.

We discuss these results in relation to needed improvements to mitigate hydrosystem impacts in the Discussion section. More detailed results and figures for each ESU can be found in Appendix A.

Tributary Habitat

Detailed results for each tributary habitat analysis are presented in Appendix B. Below we present general results.

Riparian and floodplain functions. Riparian and floodplain corridors in agricultural and urban areas had substantially smaller buffers than riparian and floodplain areas in other land-use types. Areas with a particularly high proportion of riparian and floodplain corridors in these two land-uses included the Umatilla and Walla Walla, portions of the Grande Ronde drainage, the Pahsimeroi River and a substantial portion of the lower Columbia occupied by chum salmon (see Figure Sets 2 and 3).

Surface erosion on non-forested lands. Populations with the greatest increase in potential sedimentation from reference conditions for non-forested lands included those in the lower reaches of the Snake River, the Walla Walla and Umatilla, and the Cowlitz, Scappoose, Salmon and Washougal in the Lower Columbia (for chum) (Figure Set 4).

Mass wasting and surface erosion on forested lands. Mass wasting and surface erosion increased most dramatically for populations in the upper reaches of the John Day River, the Klickitat River, some areas of the Grande Ronde and nearly all of the areas occupied by Columbia River chum salmon (Figure Set 5).

In-stream flow regime. Areas with the greatest proportion of mean low flow that is legally allotted include the lower elevation areas of Central Oregon, as well as the Walla Walla, Umatilla, portions of the upper Salmon River, the Upper Yakima and the Okanogan. (Figure Set 6).

Diversion entrainment. Populations with the highest potential for diversion entrainment included those in the Okanogan and Methow Rivers, portions of the Grande Ronde, the Lemhi and other areas in the upper Salmon River. Again, data made available to us did not include information about current screening status, so this assessment is properly viewed as a relative measure of the potential for entrainment. Local information, when available, can help refine this evaluation (Figure Set 7).

Water Quality. Those populations with the highest likely exposure to pesticides were located in the lower Snake River basin, portions of the Upper Columbia in the interior basin, and in about half of the areas occupied by chum salmon populations (Figure Set 8). This water quality metric is very coarse, and provides only a relative measure of potential pesticide impacts.

Barriers. Our evaluation of areas rendered inaccessible by anthropogenic barriers was limited by data availability. Thus, our results should be viewed as an initial investigation of blocked areas rather than a definitive analysis. [Note that we are currently engaged in an explicit comparative analysis for several subbasins using locally-provided barrier data.] While several populations have been extirpated by anthropogenic barriers (White Salmon River steelhead, North Fork Clearwater steelhead, one or more steelhead populations in the upper Deschutes drainage), the majority of populations, with a few exceptions, did not appear to have large amounts of habitat blocked. The most affected chinook population was Catherine Creek, with up to 22% of historically available stream miles blocked. Camas Creek, the Wenatchee River and the North Fork Salmon River also had relatively high proportions of blocked area, in comparison with other chinook populations. The range of area blocked was somewhat higher for steelhead, with the Umatilla River population having nearly 40% of historically available area potentially blocked (Figure Set 9). This is an obvious potential area of impairment for anadromous salmonids that could benefit tremendously from improved data quantity and quality.

Absolute values for each of these factors for each population are presented in Table 2. More details are presented in Appendix B.

Estuary Habitat

Our review of available information suggests that ESUs are affected differentially by estuarine factors, based on their dominant life history strategy and use of the estuary. In particular, ESUs with a dominant stream-type life history are most strongly affected by tern predation and flow (through its impact on plume habitat) (see Appendix C). ESUs with a dominant ocean-type life history, however, were most affected by changes in shallow-water habitat and in the flow regime (mediated in this case through its impact on habitat quantity and quality). See Appendix C for further details.

Population Status Assessment

Current population status. We also examined the number of viability-relevant parameters that showed the potential for improvement on a population-specific basis (Table 3). Consistent with listing under the Endangered Species Act, all populations in the Columbia basin listed ESUs that we examined showed that current population status was significantly lower than our estimate of historical status (by our metrics) in at least one parameter. Across all eight ESUs, slightly over 29 percent of the populations showed potential for improvement in all four parameters. Further details of current population status are provided in Appendix E.

DISCUSSION AND SYNTHESIS

Are necessary survival improvements biologically reasonable?

Required survival improvements for which off-site mitigation will be required have been identified in the main body of the FCRPS Biological Opinion (Table 6-6). We calculated the anticipated freshwater survival rates (FWSR) to achieve those improvements and compared them with our review of observed survival rates (Table 1) to assess the reasonableness of those rates. If, for instance, necessary freshwater survival rates exceeded robust observed survival rates by a factor of ten, the possibility that needed improvements could be achieved through freshwater habitat actions alone could realistically be called into doubt.

It is critical to remember that the point of this comparison is not to be predictive. We do not present this information as an estimate of possible improvements or as a point estimate of necessary freshwater survival rates. Rather, it is intended to inform decisions that must consider the appropriateness of off-site mitigation. In addition to the uncertainty inherent in a modeling effort, this comparison is conducted at the ESU level. Particular populations may well have freshwater survival rates that are higher or lower than our estimated current freshwater survival rates and thus have lesser or greater potential to realize improvements. In addition, very few studies quantifying steelhead freshwater survival in the Columbia, or wild steelhead freshwater survival anywhere in its native range were available, making these survival rate estimates somewhat more challenging to interpret. Nonetheless, this analysis can provide some important perspective about the identified gap and the potential for filling it with the use of off-site mitigation.

To address this question, we conducted two types of comparisons. First, we assumed that all changes would occur in a density-dependent, deterministic fashion. We applied the percent change in survival to the calculated or assumed current freshwater survival rate (the egg-to-smolt phase) to determine the necessary FWSR if that gap were filled. We did not calculate these values for Snake River sockeye or for Columbia River chum, as current FWSRs were not available for either ESU. Then, for Snake River steelhead and spring/summer chinook (for which we were able to generate stochastic, density-dependent matrices), we also determined the necessary survival rate assuming that all the change occurred in the egg-parr stage (i.e. before density-dependence), and assuming that all the change occurred by increasing the ceiling or capacity of the system.

Density-independent comparisons.

The current (calculated) FWSR for the three chinook ESUs included in our analysis (Snake River spring/summer chinook, Upper Columbia spring chinook and Snake River fall chinook) all fell within the range of observed freshwater survival rates (Table 4). Survival gaps ranged from 0.7% to 4.3%; in each case the necessary improved FWSR also fell within the observed range. Both current and necessary FWSR for the Upper Columbia ESU was at the high end of the observed range, however. This suggests that there is a reasonable likelihood that survival rates for these ESUs can be improved through off-site mitigation (in those cases where habitat has been degraded).

This picture is slightly more complex for steelhead ESUs. Current (calculated) FWSRs for Snake River steelhead and Upper Columbia steelhead were both higher than observed FWSRs for steelhead (Table 4). (We were unable to construct a matrix for Mid-Columbia steelhead, and therefore used the average of the other two ESUs for its "current" FWSR.) It is possible that this discrepancy is merely due to a lack of data; studies of total steelhead freshwater survival rates in the wild were very rare. While there were more studies of smaller segments of the life-cycle (e.g. fry-to-1+ survival rates), nearly all of these involved hatchery fish, and many involved steelhead outside their native range. As a potential point of comparison, if we assume that the current survival rate is equal to the midpoint of the observed range (i.e. 0.94), necessary survival rates for Snake River steelhead (0.95%) also fall within the observed range. However, in this case, necessary survival rates for Upper Columbia steelhead and populations within the Mid-Columbia steelhead ESU (1.99%) would exceed the observed range. Clearly, some refinement is needed in this case, as it is difficult to gauge whether the observed range or our estimate of current rates is likely to be more unrealistic.

Density-dependent comparisons.

Data availability for both the Snake River spring/summer chinook and Snake River steelhead ESUs allowed us to calculated a Leslie matrix that included density-dependence and stochasticity (Appendix A). Adding these additional factors to the population dynamics provided some additional considerations. Necessary FWSRs to close the survival gap increased if those survival increases occurred during a time period when density-dependence was applied (Table 5). In other words, a greater increase in survival was required if the targeted life stage is subject to density-dependent mortality. In addition, improving the capacity of the system (alone) has a greater effect on mean population growth rates than improving the productivity of the system, subjected to density-dependence (Figure 1, Appendix A). This suggests that in systems where density-dependence is operating, a greater survival increase may be needed than that predicted by simple, density-independent models. It also suggests that actions that increase survival during density-independent life-stages, or that increase the capacity of the system together with survival have the greatest potential to effect changes in population status. Importantly, increasing the capacity of the system is not necessarily tied to opening currently inaccessible habitat. The capacity of the system to support parr may be increased by actions that aim to improve freshwater survival rates.

Gauging the Magnitude and Coincidence of Tributary Habitat Impairments

Tributary habitat throughout the interior Columbia River basin has sustained substantial impacts (Figure Sets 2-9). Interestingly, although the majority of our habitat factor evaluations relied heavily on patterns of historical and current land use, the impacts for each factor are not distributed identically across the basin. It is important to remember however, that our analysis identifies the potential or likelihood that habitat processes are impaired. Ground-truthing and refining our assessment will be an important next step.

We counted the number of factors, excluding barriers to passage, that were impaired in each population in order to identify areas that appear to be highly compromised and those with minimal habitat impacts (Table 6). We applied two standards to gauge impairment. First, we counted only those factors with a score of 8 or greater (i.e. in the upper thirtieth percentile) as impaired. Because the distribution of degree of impairment tended to be highly skewed, with most observations falling in the lower (relatively unimpaired) bins, this standard has the effect of identifying those situations in which the degree of impairment is relatively severe compared to the remainder of the basin. (We term this the "stringent" definition of impairment.) Next, we counted those factors with a score of 6 or greater (i.e. in the upper half of the range). This criterion (the "relaxed" definition of impairment) has the effect of identifying a broader range of factors that are impaired in any population. However, the likelihood that these factors all have the potential to make significant contributions to population status in each case is somewhat lower, since the degree of impairment identified is lower. We do not present these two different definitions merely to be confusing; instead, we hope that these two standards will help display the magnitude of the likely impacts.

Examining these cumulative impacts spatially reveals several interesting patterns. First, under the stringent criterion, a significant portion of the entire Salmon River basin as well as several populations in the Grande Ronde and Clearwater drainages show no habitat impacts at this level. On the other end of the spectrum, some areas within Grande Ronde, the Yakima, the Umatilla and the Walla Walla drainages, as well as some portions of the lower Columbia River show highly compromised habitats (Figure Set 10). Under the relaxed definition, highly compromised habitats are found in the Grande Ronde drainage, the Lemhi basin, portions of the South Fork of the Salmon, as well as throughout the Upper Columbia. Habitats without impacts at this level are restricted almost entirely to the Middle Fork of the Salmon River, which is largely included in designated wilderness areas (Figure Set 11).

Overall Current Population Status

With this distribution of improvement potential, most populations are showing relatively poor overall population status. Those with 3 or more viability-relevant parameters impaired are distributed widely across the Columbia basin, with all but one extant population in the Upper Columbia ESUs having the potential for improvement in all four parameters (Figure Set 12). We have not incorporated any information about the degree of change in any parameter from historical into our evaluation, in part because of apparent differences between states in characterization of current distribution. (Differences in this characterization have the potential impact of biasing the apparent magnitude of difference between current and historical distribution.

Implications of Tributary Habitat and Population Status for Off-site Mitigation

We did not take the step of quantifying how much restoration, or which particular actions would be sufficient to close the survival gap between the two hydropower scenarios. Such an exercise would require an accurate model or set of models describing (1) how restoration actions alter habitat-forming processes and habitat conditions and (2) how altered habitat conditions affect the four VSP parameters. Analyses or models linking restoration actions to some habitat conditions or habitat-forming processes (e.g., riparian function models or sediment transport models) do exist, but are not typically applicable at the scale of the Columbia River Basin. Other classes of factors (such as instream flow or toxics) are even less well-described. Moreover, it is currently not possible to evaluate combined effects of multiple processes on stream habitat conditions. Analyses or models that attempt to link habitat conditions to the four VSP parameters can be broadly classified as either simple empirical models that cannot represent complex interactions, or complex models that largely rely on professional opinion for input parameters (Beechie et al. 2003b). Neither group of models has been evaluated thoroughly enough to ascertain its suitability for application to this problem. Hence, there is currently no single model available that can be used to assess how much off-site mitigation is likely to close the survival gap for multiple populations across a landscape as large as the Columbia River basin.

We recognize that this leaves an area of uncertainty for policy-makers as they make decisions about the scope of mitigation actions that should be required. We have therefore identified populations in terms of the likelihood that habitat improvements will lead to improved VSP status. These analyses do not directly identify which actions are sufficient for recovery, but do identify for policy makers (1) which populations are not likely to improve through any combination of habitat actions, (2) which populations have a relatively high likelihood of improvement, and (3) populations for which the likelihood of improvement is uncertain (Tables 7 and 8, Figure Sets 13 and 14). Our categories are as follows:

- *Minimally compromised habitat*. No habitat factors were found to be above the impairment threshold for populations in this category. [Impairment threshold = upper thirtieth percentile for the “stringent” definition, or upper fiftieth percentile for “relaxed” definition.] There is likely little potential for actions in freshwater habitat addressing the factors we examined to improve population status substantially. (However, local information may identify impacts not considered in this study.) We identified two subsets of this category.

    - *Relatively less poor current population status*. These populations had only one or two out of the 4 viability-relevant parameters impaired. Because of the combination of relatively less poor status and strong habitat conditions, these areas may be candidates to serve as “refugia” or to receive high priority for protection.
    - *Poor population status*. These populations showed potential to improve with respect to three or four of the four VSP parameters.
- *Highly compromised habitats*. Next, we identified highly compromised habitats (i.e. many factors identified as impaired within the population) with significant population losses. It is in these areas that there is the greatest likelihood that habitat process impairments have substantially affected population status. The greatest potential to improve population status through habitat actions thus also probably lies in these situations. However, the magnitude of effort required to achieve potential improvements is also likely to be large.
- *Moderately compromised habitats.* Populations with moderately compromised habitats and significant population losses. Dependent upon the factors identified as impaired, there may be a lower likelihood that habitat conditions are substantially affecting population status in these situations. However, if there is high certainty that the identified factor is affecting the population, then the overall magnitude of restoration necessary may be somewhat less than in highly compromised situations. We also identified one subset of this category.
    - *Habitat impacts restricted to biologically identifiable factors.* We identified those areas with significant population losses and habitat impacts restricted to in-stream flows and/or diversion entrainment. We singled this group of populations (a subset of the above category) out because the remedy for these problems is biologically straightforward. In the case of diversion entrainment, the impact on the population is also straightforward and readily identifiable (and therefore likely more certain). These may provide opportunities for restoration. [It is important to remember, however, that this analysis identifies the POTENTIAL for diversion entrainment to be a problem, not an actual measure, since data about the presence or quality of screens on diversions is lacking.]

These categories provide some general context for interpreting the potential for tributary habitat actions to affect positively population status. Those populations with minimally compromised habitat, for instance, provide little apparent opportunity for habitat restoration (across the range of factors that we examined); engaging solely in tributary habitat actions to improve population status in these cases would be a relatively high risk strategy, if local information does not indicate other problems. A lower-risk strategy for these populations would include actions with greater certainty of achieving a response. Those populations with highly and moderately compromised habitat are more likely to show a response to habitat improvements. Importantly, the likelihood of a response will be affected not only by the diversity of habitat factors impaired in an area, but also by the magnitude of change from historic conditions, the certainty with which changes (improvement) in a particular factor can be linked to population response.

Ultimately, a strong monitoring and evaluation program will also be necessary in any mitigation effort to determine whether anticipated improvements have, in fact, been realized.

ESU and Population-specific Discussion

Opportunities for off-site mitigation in tributary and estuarine habitats to improve population and ESU status vary from ESU to ESU. We discuss them individually below.

In the Upper Columbia spring chinook and steelhead ESUs, regardless of whether the stringent or relaxed definition of tributary habitat impairment is applied, all populations show some degree of habitat impairment. Thus, there are likely to be some opportunities, biologically-speaking, to improve population status through off-site mitigation efforts aimed at freshwater habitats. However, the magnitude of these improvements is uncertain.

In the Snake River spring/summer chinook and steelhead ESUs, the situation is somewhat more complicated. Twenty-three to fifty percent of the populations in the chinook ESU, and eleven to thirty-five percent of the populations in the steelhead ESU in this drainage (dependent upon whether the stringent or relaxed criterion is applied) show minimal habitat process impairments over the range of factors that we examined. Notably, all the populations in one major population grouping of the spring/summer chinook ESU (the Middle Fork Salmon) are rated as having this minimal potential for improvement through tributary habitat actions. The remaining populations show some degree of opportunity to improve population status through off-site mitigation, with several showing impairment over many of the factors examined. These latter situations have the highest likelihood that habitat process impairments have substantially affected population status, thus providing off-site mitigation opportunities. However, as with the Upper Columbia spring chinook ESU, the magnitude of these improvements is uncertain. One particular note for this ESU: our analyses indicate that the South Fork Salmon River generally has a relatively low degree of impairment to habitat processes. However, this area has been notorious for sedimentation issues. This apparent discrepancy is due to the focus of our analyses on current conditions and practices (e.g. current timber harvest regimes, which are much reduced compared to historic timber harvest levels).

The Mid-Columbia steelhead ESU is somewhat less variable. Of sixteen extant populations, only 1-2 (dependent on the criterion) populations show minimal impacts, with the remainder having at least one factor classified as impaired. Populations in the Walla Walla, Umatilla and Yakima drainages are particularly highly compromised. Thus, although the magnitude is uncertain, there are likely to be some opportunities to improve population status through offsite mitigation efforts aimed at freshwater habitats in most major population groupings in this ESU.

All five of the above ESUs display a dominant stream-type life history strategy. Our evaluation indicates that there may also be some biological potential through reductions in tern predation or plume habitat (altered flow regime) to affect population status for these ESUs.

The Snake River fall chinook ESU generally showed minimal impact in the habitat factors we evaluated. However, these fish, which use mainstem habitats as a spawning area are more likely to be affected by other habitat factors, such as mainstem temperatures and flows. Thus, additional work (including synthesis of previous analyses) is called for in this case.

All populations in the Columbia River chum population showed some degree of habitat impairment by our analysis. Thus, as with the Upper Columbia ESUs, there is likely to be some opportunity to improve the status of component populations through habitat actions.

In addition, both the Snake River fall chinook and Columbia River chum use the estuary as relatively small (sub-yearling) fish. Our evaluation suggests that there may be additional opportunities in the estuary, through shallow-water habitat improvement, flow changes (affecting shallow water habitat) and reduction of toxic impacts for these ESUs.

The Snake River sockeye ESU, clearly challenged in many ways, shows minimal impact in the habitat screens completed. However, we have not yet conducted analyses relating to water diversions for this population. Nonetheless, opportunities for habitat improvement for this ESU are likely to be low.

Summary

This is a coarse-scale, basin-wide examination of a variety of tributary and estuarine habitat factors, and the potential for off-site mitigation aimed at those factors to affect population status positively. We found substantial variation between geographic areas in the likely degree of impact of these various factors. For example potential for forest sediment increases were most marked in the lower Columbia River, the east slopes of the Cascades and several forested areas in the interior basin, whereas impacts related to irrigation were concentrated in the lower elevation areas of central Washington and Oregon as well as the Lemhi River of Idaho. ESUs varied in the number and proportion of populations for which it was likely that there was biological potential for estuarine or tributary habitat off-site mitigation to affect population status. All populations in the Upper Columbia ESUs and the Columbia River chum had at least some habitat impairment. Snake River ESUs, however, had substantial portions, most notably in the Middle Fork of the Salmon River drainage, with no habitat impacts identified in this set of analyses (at the two levels of impairment that we identified). Our analysis was limited, however, and did not include any assessment of impacts related to mining, nutrient cycling, and exotic species, for example (see also notes for specific analyses for limitations to specific analyses). Conditions in the estuary and plume appeared to have a differential impact on different ESUs, with those ESUs with stream-type life histories likely to be more affected by plume conditions and tern predation, and those ESUs with ocean-type life histories likely to be more affected by the quality and quantity of shallow-water habitat and toxics.

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Table 1. Observed egg-smolt (freshwater) survival rates for ocean-type chinook salmon, stream-type chinook salmon and steelhead trout.

Species and Lifestage	Origin	Survival Rates (%)					Location	Reference
		Low	Mean	High	St. Dev.	No. of years		
Ocean-type Chinook								
Egg-fingerling	wild	0.11	3.98	16.85	4.15	14	Qualicum R., B.C.	(Fraser et al. 1983)
Egg-smolt	wild	6.8	14.0	30.7	11.2	4	Fall Ck., CA	(Wales and Coots 1954)
Mean		**3.5**	**9.0**	**23.8**				
Stream-type Chinook								
Egg-smolt	wild	0.02	4.40	8.20	2.00	15	Tucannon R., WA	(Gallinat et al. 2001)
Egg-smolt	wild	2.1	4.6	8.7	2.8	7	Warm Springs R., OR	(Lindsay et al. 1989)
Egg-smolt	wild	1.27	5.76	10.61	3.01	8	Yakima R., WA	(Fast et al. 1991)
Egg-smolt	wild	2.6	5.4	8.6	2.3	5	John Day R., OR	(Knox et al. 1984)
Egg-smolt	wild	4.6	9.1	19.6	6.3	5	Chiwawa R. ,WA	(Murdoch et al. 2001)
Egg-smolt	wild	6.4	9.6	14.2	3.0	5	Lookinglass Cr., OR	(Burck 1993)
Egg-smolt	wild	5.4	10.7	16.4	4.6	5	Yakima R., WA	(Major 1969)
Egg-smolt	wild	4.0	9.8	15.9	3.2	8	Lemhi R., ID	(Bjornn 1978)
Mean		**3.30**	**7.42**	**12.78**	**-**	**-**		
Steelhead								
Egg-smolt	wild	0.28	0.70	1.30	0.39	7	Keogh R., B.C.	(Ward 1993)
Egg-smolt	wild	-	1.60	-	-	9	Snow Cr. Res. Stn., WA	T. Johnson and R. Cooper pers. comm. cited (Bley and Moring. 1988).
Mean		**0.28**	**1.27**	**1.30**				

Table2. Population-level values for seven habitat factors examined. See Appendix B for details of specific analyses.

			Nonforest Sediment			FOREST SEDIMENT	FLOODPLAIN	Riparian		Toxics	Diversions		Barriers
ESU and Major Population Grouping	Current Pop. Code	Population Name	Historical[1]	Current	Increase	Increase	% converted[2] (potential range)	% converted[3] (current range)	% converted[3] (potential range)	Avg. water quality rating	Entrainment Rating (No. of diversions)	% Flow Diverted	% Weighted stream km blocked (worst case scenario)
Snake River Spring / Summer Chinook													
Lower Snake River	SNASO	Asotin River	0.576	3.207	3.945	1.626	10.093	0.000	20.320	1.297	318	0.676	0.00
	SNTUC	Tucannon River	1.269	6.362	3.797	1.330	34.005	3.391	41.311	1.395	340	5.86	0.00
Grande Ronde / Imnaha	GRWEN	Wenaha River	0.180	0.349	1.037	1.382	0.000	0.000	0.000	1.001	304	0.3	0.00
	GRLOS	Wallowa/Lostine Rivers	0.279	0.972	1.922	1.493	45.650	46.425	25.478	1.192	535	19.87	4.61
	GRLOO	Lookingglass Creek (historic)	0.008	0.042	1.034	3.264	0.000	0.000	0.000	1.000	308	333.63	0.00
	GRMIN	Minam River	0.290	0.773	1.232	1.063	0.000	0.000	0.563	1.003	307	0.21	0.00
	GRCAT	Catherine Creek	0.354	1.043	1.877	1.906	77.393	17.552	18.137	1.359	595	122.6	9.79
	GRUMA	Upper Grande Ronde River	0.078	0.179	1.188	2.193	22.662	0.000	0.597	1.077	390	74.02	0.00
	IRMAI	Imnaha River	0.620	0.833	1.119	1.279	0.000*	0.000	0.000	1.002	330	3.85	0.00
	IRBSH	Big Sheep Creek	0.554	1.772	2.110	1.407	0.000*	0.000	0.225	1.003	319	3.43	0.00
South Fork Salmon River	SRLSR	Little Salmon River	0.186	0.889	1.474	2.028	24.201*	0.368	11.945	1.025	479	40.49	0.00
	SFMAI	South Fork Salmon River	0.125	0.145	1.003	1.360	5.228*	0.293	1.176	1.004	370	8.53	0.00
	SFSEC	Secesh River	0.000	0.000	1.000	1.475	0.799*	1.136	0.591	1.000	348	0.5	0.00
	SFEFS	E Fk S Fk Salmon River	0.007	0.007	1.000	1.414	3.301*	3.473	1.434	1.016	352	1.34	0.00
Middle Fork Salmon River	SRCHA	Chamberlain Creek	0.028	0.028	1.000	1.128	0.000*	0.000	0.338	1.001	347	1.49	0.00
	MFBIG	Big Creek	0.555	0.555	1.000	1.058	0.000*	0.066	0.037	1.000	354	2.27	0.00
	MFLMA	Lower Middle Fork Salmon River	0.980	0.980	1.000	1.009	6.274*	0.000	0.803	1.000	348	3.23	0.00
	MFCAM	Camas Creek	0.161	0.161	1.000	1.070	0.000*	1.264	0.308	1.000	348	2.78	6.57
	MFLOO	Loon Creek	0.231	0.231	1.000	1.034	4.365*	2.676	1.557	1.000	347	0.85	0.00

Table2. Population-level values for seven habitat factors examined. See Appendix B for details of specific analyses.

			Nonforest Sediment			FOREST SEDIMENT	FLOODPLAIN	Riparian		Toxics	Diversions		Barriers
ESU and Major Population Grouping	Current Pop. Code	Population Name	Historical[1]	Current	Increase	Increase	% converted[2] (potential range)	% converted[3] (current range)	% converted[3] (potential range)	Avg. water quality rating	Entrainment Rating (No. of diversions)	% Flow Diverted	% Weighted stream km blocked (worst case scenario)
	MFUMA	Upper Middle Fork Salmon River	0.189	0.189	1.000	1.024	0.000*	0.237	0.702	1.000	349	2.71	0.00
	MFSUL	Sulphur Creek	0.010	0.010	1.000	1.007	0.336*	4.638	2.438	1.005	347	0.79	0.00
	MFBEA	Bear Valley Creek	0.028	0.028	1.000	1.046	0.000*	0.000	0.000	1.000	348	2.66	0.00
	MFMAR	Marsh Creek	0.071	0.071	1.000	1.032	0.000*	0.000	0.369	1.003	352	3.3	0.00
Upper Salmon River	SRPAN	Panther Creek (historic)	0.193	0.193	1.000	1.396	4.770*	1.679	1.373	1.000	367	1.29	0.00
	SRNFS	N Fk Salmon River	0.198	0.198	1.000	1.640	13.950*	16.760	10.903	1.009	413	12.66	0.00
	SRLEM	Lemhi River	0.607	0.690	1.062	1.230	38.244*	44.524	22.634	1.095	891	36.83	1.04
	SRLMA	Lower Salmon River	1.192	1.209	1.007	1.193	26.512*	21.144	13.102	1.047	804	52.98	0.00
	SRPAH	Pahsimeroi River	0.916	0.922	1.004	1.145	31.149*	37.941	12.986	1.054	574	47.22	0.00
	SREFS	E Fk Salmon River	1.499	1.499	1.000	1.040	6.365*	7.079	1.717	1.003	625	18.65	0.00
	SRYFS	Yankee Fork	0.097	0.097	1.000	1.306	0.000*	0.000	0.000	1.000	585	6.82	0.00
	SRVAL	Valley Creek	0.126	0.126	1.000	1.239	10.408*	11.144	12.056	1.046	625	10.44	7.39
	SRUMA	Upper Salmon River	0.175	0.175	1.000	1.284	5.174*	7.090	4.245	1.072	658	3.09	0.00
Snake River Fall Chinook													
Snake River	SNTUC	Tucannon River - North	0.226	0.410	1.075	1.313	34.005	0.643	41.342	1.390	340	5.86	NA
	SNTUC	Tucannon River - South	1.271	6.372	3.803	1.313	34.005	17.332	41.311	1.390	340	5.86	NA
	GRLMT	Grande Ronde River lower mainstem tributary	0.477	2.166	2.145	1.744	2.350	0.000	12.611	1.146	313	3.63	NA
	CRLMA	Clearwater River lower mainstem	0.514	4.137	5.166	1.474	15.351*	5.719	23.810	1.485	313	313	NA
	SRLSR	Little Salmon and Rapid River	0.328	1.265	1.529	1.616	24.201*	0.000	9.307	1.039	479	40.49	NA
	SNHCT	Snake River Hells	0.788	1.484	1.359	1.252	0.000*	0.000	0.000	1.005	313	313	NA

Table2. Population-level values for seven habitat factors examined. See Appendix B for details of specific analyses.

			Nonforest Sediment			FOREST SEDIMENT	FLOODPLAIN	Riparian		Toxics	Diversions		Barriers
ESU and Major Population Grouping	Current Pop. Code	Population Name	Historical[1]	Current	Increase	Increase	% converted[2] (potential range)	% converted[3] (current range)	% converted[3] (potential range)	Avg. water quality rating	Entrainment Rating (No. of diversions)	% Flow Diverted	% Weighted stream km blocked (worst case scenario)
		Canyon tributaries											
	IRMAI	Imnaha River mainstem	0.618	0.834	1.122	1.279	0.000*	0.000	0.000	1.002	330	3.85	NA
Upper Columbia Chinook													
Upper Columbia	UCENT	Entiat River	0.093	0.132	1.009	2.179	3.712	5.746	6.860	1.059	580	29.64	0.00
	UCMET	Methow River	0.130	0.225	1.064	1.603	6.042	7.313	10.215	1.077	840	66.835	0.86
		Okanogan River (historic)	0.059	0.721	4.592	1.535	0.197	16.969	8.679	1.227	NA	NA	
	UCWEN	Wenatchee River	0.142	0.308	1.043	1.778	3.241	1.860	12.121	1.178	581	1444.72	2.32
Lower Columbia Chum													
Lower Columbia	GRAY-CM	Grays & Chinook Rivers	NA	0.016	1.166	3.728	11.230	17.419	18.041	1.038	NA	NA	0.30[4]
	YOUN-CM	Youngs Bay	NA	0.008	1.136	3.566	10.270	19.515	16.068	1.076	NA	NA	6.17[4]
	BIGC-CM	Big Creek	NA	0.014	1.245	2.909	25.720	0.177	0.000	1.083	NA	NA	24.01[4]
	ELOC-CM	Elochoman River	NA	0.037	1.427	3.164	32.670	45.010	44.695	1.123	NA	NA	21.22[4]
	CLAT-CM	Clatskanie River	NA	0.040	1.752	2.399	21.810	11.912	4.336	1.272	NA	NA	0.05[4]
	MILL-CM	Mill Creek	NA	0.017	1.309	2.497	7.200	39.547	7.321	1.775	NA	NA	2.77[4]
	COWL-CM	Cowlitz River	NA	0.065	2.039	2.638	31.290	26.039	17.750	1.419	NA	NA	13.58[4]
	KALA-CM	Kalama River	NA	0.012	1.043	3.486	9.390	18.270	28.856	1.080	NA	NA	5.41[4]
	SCAP-CM	Scappoose River	NA	0.100	2.439	2.285	31.110	25.693	27.067	2.058	NA	NA	11.58[4]
	LEWS-CM	Lewis River	NA	0.067	1.731	2.465	13.850	20.717	27.581	1.314	NA	NA	37.5[4]
	SALM-CM	Salmon Creek	NA	0.105	3.126	1.924	46.410	53.751	61.253	4.390	NA	NA	15.69[4]
	CLCK-CM	Clackamas River	NA	0.023	1.276	2.048	42.850	67.918	64.381	3.936	NA	NA	11.96[4]
	WASH-CM	Washougal River	NA	0.097	1.962	2.634	14.440	15.640	20.836	1.490	NA	NA	57.32[4]

Table2. Population-level values for seven habitat factors examined. See Appendix B for details of specific analyses.

			Nonforest Sediment			FOREST SEDIMENT	FLOODPLAIN	Riparian		Toxics	Diversions		Barriers
ESU and Major Population Grouping	Current Pop. Code	Population Name	Historical[1]	Current	Increase	Increase	% converted[2] (potential range)	% converted[3] (current range)	% converted[3] (potential range)	Avg. water quality rating	Entrainment Rating (No. of diversions)	% Flow Diverted	% Weighted stream km blocked (worst case scenario)
	SAND-CM	Sandy River	NA	0.102	1.631	2.162	11.370	22.870	16.962	1.650	NA	NA	23.88[4]
	LGRG-CM	Lower Gorge Tributaries	NA	0.010	1.079	2.024	15.760	16.426	14.382	1.070	NA	NA	0.83[4]
	UGRG-CM	Upper Gorge Tributaries	NA	0.024	1.127	1.785	11.480	6.149	27.677	1.230	NA	NA	30.45[4]
Snake River Sockeye													
Upper Salmon River	SRRED	Redfish Lake	0.252	0.252	0.000	1.057	NA	NA	NA	1.005			
	SRRED	Alturas Lake	0.001	0.001	0.000	1.330	NA	NA	NA	1.010			
	SRRED	Petit Lake	0.008	0.008	0.000	1.118	NA	NA	NA	1.030			
Middle Columbia Steelhead													
Cascade Eastern Slope Tributaries	MCWSA-s	While Salmon River (historic)	0.006	0.006	1.000	2.382	0.562	0.438	0.190	1.124	30	0.26	92.71
	MCKLI-s	Klickitat River	0.172	0.502	1.265	2.428	13.451	4.072	4.149	1.102	76	23.16	7.86
	MCFIF-s	Fifteen Mile Creek (winters)	1.243	4.224	2.393	1.684	23.507	16.191	25.054	1.391	231	3.92	2.29
	DREST-s	Deschutes River, Eastside	1.426	1.981	1.292	1.245	11.997	3.168	9.054	1.110	95	22.64	7.28
	DRWST-s	Deschutes River, Westside	0.531	0.636	1.072	1.460	1.331	1.612	0.354	1.032	57	0.21	1.59
		Crooked River - Above Pelton Dam (historic)	0.417	0.455	1.066	1.395	0.020	5.803	3.102	1.077	NA	NA	
	DRUMA-s	Upper Deschutes/Squaw creek - Above Pelton Dam (historic)	0.332	0.434	1.154	1.743	0.086	4.851	3.933	1.220	NA	NA	
	MCROC-s	Rock Creek	1.379	3.295	1.949	1.421	0.000	0.000	1.922	1.101	47	0.04	0.00
John Day River	JDLMT-s	John Day River	1.552	1.934	1.196	1.256	17.155	6.207	17.028	1.134	412	2142.95	3.35

Table2. Population-level values for seven habitat factors examined. See Appendix B for details of specific analyses.

			Nonforest Sediment			FOREST SEDIMENT	FLOODPLAIN	Riparian		Toxics	Diversions		Barriers
ESU and Major Population Grouping	Current Pop. Code	Population Name	Historical[1]	Current	Increase	Increase	% converted[2] (potential range)	% converted[3] (current range)	% converted[3] (potential range)	Avg. water quality rating	Entrainment Rating (No. of diversions)	% Flow Diverted	% Weighted stream km blocked (worst case scenario)
		lower mainstem tribs											
	JDNFJ-s	North Fork John Day River	0.363	0.486	1.072	2.126	5.558	1.460	1.370	1.020	404	617.30	0.34
	JDMFJ-s	Middle Fork John Day River	0.456	0.744	1.203	2.314	2.343*	2.783	3.244	1.012	389	179.34	0.00
	JDSFJ-s	South Fork John Day River	0.568	0.592	1.010	1.775	25.997*	8.951	5.021	1.003	329	27.28	0.02
	JDUMA-s	John Day upper mainstem	0.536	0.653	1.068	1.809	56.625*	16.211	27.496	1.047	743	119.19	3.11
Umatilla and Walla Walla Rivers	MCUMA-s	Middle Fork Salmon River upper mainstem	0.573	2.374	3.365	1.360	60.657	27.436	31.201	1.341	476	1992.08	35.04
	WWMAI-s	Walla Walla River	1.341	4.952	3.103	1.304	67.687	34.798	72.102	2.056	964	17129.18	7.67
	WWTOU-s	Touchet River	1.751	7.234	3.523	1.174	62.094	19.366	67.806	1.634	552	178.48	0.00
Yakima River Group	YRTOS-s	Toppenish and Satus Creeks	1.326	1.742	1.199	1.503	32.079	3.752	4.115	1.155	315	19.92	0.15
	YRNAC-s	Naches River	0.286	0.608	1.153	1.736	15.769	18.552	13.351	1.220	660	215.76	17.12
	YRUMA-s	Yakima River upper mainstem	0.586	0.775	1.115	1.902	20.858	10.071	24.738	1.207	823	289.92	21.00
Snake River Steelhead													
Lower Snake	SNTUC-s	Tucannon River	1.378	6.179	3.528	1.298	30.342	6.833	41.342	1.385	343	10.27	0.00
	SNASO-s	Asotin Creek	1.164	6.120	4.677	1.198	48.174	7.960	59.625	1.506	415	107.55	0.54
Clearwater River	CRLMA-s	Clearwater lower mainstem	0.514	4.136	5.161	1.474	15.351*	9.469	23.816	1.492	581	49.12	0.85
	CRNFC-s	North Fork Clearwater (historic)	0.012	0.047	1.026	2.029	0.000*	0.085	0.045	1.002	322	3.73	100.00
	CRLOL-s	Lolo Creek	0.132	0.479	1.244	2.181	0.007*	0.000	0.494	1.085	336	3.70	0.00
	CRLOC-s	Lochsa River	0.007	0.007	1.000	1.553	0.000*	0.000	0.000	1.005	381	3.74	0.00
	CRSEL-s	Selway River	0.005	0.005	1.000	1.169	0.000*	0.000	0.000	1.000	388	4.34	0.00

Table2. Population-level values for seven habitat factors examined. See Appendix B for details of specific analyses.

			Nonforest Sediment			FOREST SEDIMENT	FLOODPLAIN	Riparian		Toxics	Diversions		Barriers
ESU and Major Population Grouping	**Current Pop. Code**	**Population Name**	**Historical[1]**	**Current**	**Increase**	**Increase**	**% converted[2] (potential range)**	**% converted[3] (current range)**	**% converted[3] (potential range)**	**Avg. water quality rating**	**Entrainment Rating (No. of diversions)**	**% Flow Diverted**	**% Weighted stream km blocked (worst case scenario)**
	CRSFC-s	South Fork Clearwater River	0.004	0.033	1.033	1.817	0.000*	0.000	0.000	1.003	429	16.10	0.00
Grande Ronde River	GRLMT-s	Grande Ronde lower mainstem tribs	0.477	2.167	2.144	1.744	1.528	0.227	12.610	1.149	313	1.2	0.20
	GRJOS-s	Joseph Creek	0.574	1.194	1.555	1.588	2.743	0.714	0.642	1.005	308	2.56	0.00
	GRWAL-s	Wallowa River	0.282	0.922	1.712	1.404	36.419	25.388	22.001	1.151	536	22.43	0.90
	GRUMA-s	Grande Ronde Upper Mainstem	0.185	0.551	1.529	2.135	57.003	12.730	9.344	1.139	720	1377.66	5.54
Salmon River	SRLSR-s	Little Salmon and Rapid Rivers	0.443	1.958	1.987	1.818	23.770*	0.194	12.470	1.063	494	40.60	0.00
	SRCHA-s	Chamberlain Creek	0.091	0.092	1.000	1.253	7.214*	1.275	1.189	1.004	362	7.45	0.00
	SFSEC-s	Secesh River	0.000	0.000	1.000	1.475	0.799*	0.955	0.591	1.000	349	0.57	0.00
	SFMAI-s	South Fork Salmon River	0.035	0.035	1.000	1.352	1.954*	1.066	0.799	1.007	361	3.57	0.00
	SRPAN-s	Panther Creek	0.211	0.211	1.000	1.294	3.952*	1.588	1.264	1.000	368	1.57	4.45
	MFBIG-s	Big, Camas, and Loon Creeks	0.535	0.535	1.000	1.036	1.884*	0.805	0.549	1.000	356	4.48	3.57
	MFUMA-s	Middle Fork Salmon River Upper Mainstem	0.211	0.211	1.000	1.027	0.456*	0.269	0.558	1.001	353	3.34	0.00
	SRNFS-s	North Fork Salmon River	0.198	0.198	1.000	1.640	13.841*	6.586	10.903	1.009	413	12.64	10.44
	SRLEM-s	Lemhi River	0.607	0.690	1.062	1.230	38.298*	44.524	22.634	1.095	891	37.54	5.69
	SRPAH-s	Pahsimeroi River	1.173	1.192	1.008	1.176	30.502*	24.668	12.929	1.049	594	58.49	4.41
	SREFS-s	East Fork Salmon River	1.394	1.401	1.003	1.113	23.499*	12.141	11.187	1.029	801	35.28	2.70
	SRUMA-s	Salmon River upper mainstem	0.314	0.314	1.000	1.252	7.019*	4.766	4.993	1.048	721	53.98	2.76
Hells Canyon	SNHCT-s	Snake River Hells Canyon Tributaries	0.785	1.481	1.359	1.252	0.000*	0.000	0.000	1.005	292	0.0346	0.00

Table2. Population-level values for seven habitat factors examined. See Appendix B for details of specific analyses.

			Nonforest Sediment			FOREST SEDIMENT	FLOODPLAIN	Riparian		Toxics	Diversions		Barriers
ESU and Major Population Grouping	**Current Pop. Code**	**Population Name**	**Historical[1]**	**Current**	**Increase**	**Increase**	**% converted[2] (potential range)**	**% converted[3] (current range)**	**% converted[3] (potential range)**	**Avg. water quality rating**	**Entrainment Rating (No. of diversions)**	**% Flow Diverted**	**% Weighted stream km blocked (worst case scenario)**
Imnaha River	IRMAI-s	Imnaha River	0.594	1.211	1.427	1.327	0.000*	0.103	0.113	1.002	343	6.94	0.00
Upper Columbia Steelhead													
Upper Columbia	UCWEN-s	Wenatchee River	0.142	0.308	1.043	1.778	3.241	4.161	12.121	1.178	581	1444.71	9.44
	UCENT-s	Entiat River	0.093	0.132	1.009	2.179	3.712	4.756	6.860	1.059	580	29.62	10.56
	UCMET-s	Methow River	0.130	0.225	1.064	1.603	6.042	10.043	10.215	1.077	840	66.69	1.50
	UCOKA-s	Okanogan River	0.449	0.670	1.188	1.229	7.059	29.746	12.567	1.660	903	191.62	16.13

[1] Historical values were not calculated for the Lower Columbia due to lack of non-forested areas; these areas are indicated as NA.
[2] Percent area in 100-year FEMA floodplains converted to human-impacted land uses, except for values with an asterisk (*), for which we did not have complete FEMA floodplain data coverage available; these values were calculated as the percent stream length passing through converted land types as in the riparian analysis. We did not have data for Chinook populations CRLMA and SNHCT; values shown are the values that were calculated for steelhead in these basins. See footnote 3 for a description of NA values.
[3] NA indicates values that were not calculated for sockeye because their range is limited to lakes, whereas our screen investigated riparian areas of lotic systems
[4] These values calculated by Willamette/Lower Columbia TRT using different methods than Interior Columbia TRT. See (Steel and Sheer 2002)

Table 3. Summary of potential for improvement in population status. An "X" indicates that there is potential to improve population status for that parameter. A lower case 'x' indicates that the average value from the ESU was used. See Appendix E for specific details.

ESU	Population Name	Potential for Population Improvement			
		Abundance	*Productivity*	*Spatial Structure*	*Diversity*
Snake River Spring/Summer Chinook					
	Asotin River	X	x	X	
	Tucannon River	X	X	X	
	Wenaha River	X	X	X	X
	Wallowa/Lostine Rivers	X	X	X	X
	Lookingglass Creek (Historic)	x	x	X	X
	Minam River	X	X	X	
	Catherine Creek	X	X	X	
	Upper Grande Ronde River	X	X	X	X
	Imnaha River	X	X	X	
	Big Sheep Creek	X	X	X	
	Little Salmon River	X	X	X	
	South Fork Salmon River	X	X		X
	Secesh River	X	X		
	E Fk S Fk Salmon River		x	X	
	Chamberlain Creek	X	X		
	Big Creek	X	X	X	
	Lower Middle Fork Salmon River	X	x	X	
	Camas Creek		X	X	
	Loon Creek	X	X	X	
	Upper Middle Fork Salmon River	X	x	X	
	Sulphur Creek	X	X		
	Bear Valley Creek	X	X	X	
	Marsh Creek	X	X	X	
	Panther Creek (Historic)	X	X	X	X
	N Fk Salmon River	X	X	X	X
	Lemhi River	X	X	X	
	Upper Salmon Lower Mainstem	X	x	X	
	Pahsimeroi River	X		X	X
	E Fk Salmon River		X	X	
	Yankee Fork		X	X	
	Valley Creek		X	X	
	Upper Salmon River		X	X	
Upper Columbia Chinook					
	Entiat River	X	X	X	X
	Methow River	X	X	X	X
	Wenatchee River	X	X	X	
Snake River Fall Chinook					
	Snake mainstem and lower tributaries		X	*	*

*** No Data**

Table 3. Continued

ESU	Population Name	Potential for Population Improvement			
		Abundance	*Productivity*	*Spatial Structure*	*Diversity*
Middle Columbia Steelhead					
	White Salmon River (Historic)	X	x	X	X
	Klickitat River	X		X	X
	Fifteen Mile Creek (winters)	X		X	X
	Deschutes River, Eastside	X	X	X	
	Deschutes River, Westside	X		X	
	Rock Creek	X	x		X
	John Day River lower mainstem tribs	X	X	X	X
	North Fork John Day River		X	X	
	Middle Fork John Day River		X	X	
	South Fork John Day River	X	X	X	
	John Day upper mainstem		X	X	
	Umatilla River	X	X	X	X
	Walla Walla River	X	x	X	X
	Touchet River	X	X	X	X
	Toppenish and Satus Creeks	X	x	X	X
	Naches River	X	x	X	
	Yakima River upper mainstem	X		X	X
Snake River Steelhead					
	Tucannon River	X	X	X	
	Asotin Creek	X	X	X	X
	Clearwater lower mainstem	X	x	X	X
	North Fork Clearwater (historic)	X	x	X	X
	Lolo Creek	X	x	X	
	Lochsa River	X	x	X	
	Selway River	X	x	X	
	South Fork Clearwater River	X	x	X	
	Grande Ronde lower mainstem tribs	X	x	X	X
	Joseph Creek		x		
	Wallowa River	X		X	
	Grande Ronde Upper Mainstem	X	X	X	
	Little Salmon and Rapid Rivers	X	x	X	
	Chamberlain Creek	X	x	X	
	Secesh River	X	x	X	
	South Fork Salmon River	X	x		
	Panther Creek	X	x	X	
	Big, Camas, and Loon Creeks	X	x		
	Middle Fork Salmon River Upper Mainstem	X	x	X	
	North Fork Salmon River	X	x	X	X
	Lemhi River	X	x	X	
	Pahsimeroi River	X	x	X	X
	East Fork Salmon River	X	x	X	X
	Salmon River upper mainstem	X	x	X	X
	Snake River Hells Canyon Tributaries	X	x	X	X
	Imnaha River	X	X		X

*** No Data**

Table 3. Continued

ESU	Population Name	Potential for Population Improvement			
		Abundance	*Productivity*	*Spatial Structure*	*Diversity*
Upper Columbia Steelhead					
	Wenatchee River	X	X	X	X
	Entiat River	X	X	X	X
	Methow River	X	X	X	X
	Okanogan River	X	x	X	X
Columbia River Chum					
	Youngs Bay		x	X	X
	Grays River (Hymer)	X	X	X	
	Grays River (Rawding)			X	
	Big Creek		x	X	X
	Elochoman River		x		
	Clatskanie River		x	X	
	Mill, Abernathy, Germany		x	X	X
	Scappoose Creek		x	X	X
	Cowlitz River		x	X	X
	Kalama River	X	x	X	X
	Lewis River		x	X	X
	Salmon Creek		x	X	X
	Clackamas River		x	X	X
	Sandy River	X	x	X	X
	Washougal river		x	X	X
	Lower Gorge Tributaries	X	X	X	
Snake River Sockeye					
	Redfish Lake	X	X	X	X

Table 4. Survival gaps, current freshwater survival rate (FWSR), necessary FWSR to close the gap, and observed range of FWSR for listed interior Columbia and chum ESUs, assuming that the required change occurs in a density-independent manner. Note that we assume that freshwater survival is equivalent to egg-to-smolt survival.

ESU[1]	**Relative Survival Gap (Percent)**	**Assumed Current Freshwater Survival Rate (Percent)**	**Freshwater Survival Rate Required**	**Observed Biological Range**	
				low	**high**
Snake River spring/summer chinook	0.8	4.59	4.63	0.02	16.4
Snake River steelhead	0.7	2.29	2.31	0.28	1.6
Snake River fall chinook	19.3	0.41	0.49	0.11[2]	30.7
Upper Columbia spring chinook	4.3	9.50	9.91	0.02	16.4
Upper Columbia steelhead	8.5	3.80	4.12	0.28	1.6
Mid-Columbia steelhead[3]	8.5	3.05[4]	3.30	0.28	1.6

[1] We did not include Columbia River chum in this analysis no data were available to estimate the current freshwater survival rate. In addition, no observed freshwater survival rates were available.
[2] Note that the observed biological FWSR range for fall chinook is confined to ocean-type chinook
[3] Several Mid-Columbia steelhead populations had no survival gap. We present the maximum gap for comparison.
[4] No freshwater survival rate estimate was available for Mid-Columbia steelhead. Therefore, we assumed the average FWSR of the other two steelhead ESUs

Table 5. Necessary freshwater survival rates (FWSR) to fill the survival gap, based on density-dependent, stochastic matrices (Appendix A). We calculated the necessary survival rates three ways: 1) assuming that the change would occur in a density-dependent manner (equivalent to the value in Table 4). This is equivalent to changing both the slope and the ceiling of the Beverton-Holt function; 2) assuming that all the survival change would occur in the slope (the a term) of the Beverton-Holt function; and 3) assuming that the ceiling of the Beverton-Holt function was increased (by changing only the b term).

ESU	Relative Survival Gap (Percent)	Assumed Current Freshwater Survival Rate (Percent)	Necessary FWSR, Density-Independent Change	Necessary Percent Change in B-H slope	Necessary FWSR to achieve change in B-H slope	Necessary Percent Change in B-H ceiling	Required FWSR to achieve change in B-H ceiling
SRSS Chinook	0.8	4.59	4.63	2.78	4.71	1.39	4.62
SR Steelhead	0.7	2.29	2.31	4.07	2.39	0.84	2.31

Table 6. Population-specific ranking of relative impairment for seven freshwater habitat factors. Score indicates which bin the population was placed in for that habitat factor (Bins were determined by the range of change from historical conditions. Each range was divided into ten equal bins). A high score indicates that the habitat factor has a higher probability of being impaired for that population. Details in Appendix B.

ESU and Major Population Grouping	**Current Pop. Code**	**Population Name**	**Increase in non-forest sediment**	**Increase in forest sediment**	**Floodplain Conversion- Fema maps**	**Riparian Conversion**	**Toxics**	**Entrainment Rating**	**In-stream flow**	**# of factors with score ∃8**	**# of factors with score ∃6**
Snake River Spring / Summer Chinook											
Lower Snake River	SNASO	Asotin River	10	7	2	8	9	4	1	3	4
	SNTUC	Tucannon River	10	4	5	10	9	4	1	3	3
Grande Ronde / Imnaha	GRWEN	Wenaha River	4	5	1	1	2	4	1	0	0
	GRLOS	Wallowa/Lostine Rivers	9	6	6	9	8	7	2	3	6
	GRLOO	Lookingglass Creek (historic)	4	10	1	1	1	4	10	2	2
	GRMIN	Minam River	7	2	1	3	2	4	1	0	1
	GRCAT	Catherine Creek	8	8	10	8	9	7	10	6	7
	GRUMA	Upper Grande Ronde River	6	9	3	3	6	5	7	1	4
	IRMAI	Imnaha River	6	3	1*	1	2	4	1	0	1
	IRBSH	Big Sheep Creek	9	5	1*	2	2	4	1	1	1
South Fork Salmon River	SRLSR	Little Salmon River	8	8	4*	6	4	6	4	2	4
	SFMAI	South Fork Salmon River	3	5	1*	4	3	5	1	0	0
	SFSEC	Secesh River	1	6	1*	3	1	4	1	0	1
	SFEFS	E Fk S Fk Salmon River	1	5	1*	4	4	4	1	0	0
Middle Fork Salmon River	SRCHA	Chamberlain Creek	1	2	1*	2	2	4	1	0	0
	MFBIG	Big Creek	1	1	1*	2	1	4	1	0	0
	MFLMA	Lower Middle Fork Salmon River	1	1	1*	3	1	4	1	0	0

Table 6 (cont.)

	MFCAM	Camas Creek	1	2	1*	2	1	4	1	0	0
	MFLOO	Loon Creek	1	1	1*	4	1	4	1	0	0
	MFUMA	Upper Middle Fork Salmon River	1	1	1*	3	1	4	1	0	0
	MFSUL	Sulphur Creek	1	1	1*	4	3	4	1	0	0
	MFBEA	Bear Valley Creek	1	1	1*	1	1	4	1	0	0
	MFMAR	Marsh Creek	1	1	1*	2	2	4	1	0	0
Upper Salmon River	SRPAN	Panther Creek (historic)	1	5	1**	4	1	5	1	0	0
	SRNFS	N Fk Salmon River	1	7	2*	6	4	5	2	0	2
	SRLEM	Lemhi River	5	3	5*	8	7	10	4	2	3
	SRLMA	Lower Salmon River	4	2	1*	7	5	10	5	1	2
	SRPAH	Pahsimeroi River	4	2	5**	7	5	7	4	0	2
	SREFS	E Fk Salmon River	1	1	1**	4	2	8	2	1	1
	SRYFS	Yankee Fork	1	4	1**	1	1	7	1	0	1
	SRVAL	Valley Creek	1	3	2**	7	5	8	1	1	2
	SRUMA	Upper Salmon River	1	4	7**	5	6	8	3	1	3
Snake River Fall Chinook											
Snake River	SNTUC	Tucannon River - North	5	4	5	10	9	4	1	2	2
	SNTUC	Tucannon River - South	10	4	5	10	9	4	1	3	3
	GRLMT	Grande Ronde River lower mainstem tributary	9	7	3	7	7	2	7	1	5
	CRLMA	Clearwater River lower mainstem	10	5	2*	9	9	NA	NA	3	3
	SRLSR	Little Salmon and Rapid River	8	6	4**	6	5	6	4	1	4
	SNHCT	Snake River Hells Canyon tributaries	7	3	1*	1	3	NA	NA	0	1
	IRMAI	Imnaha River mainstem	6	3	1*	1	2	4	1	0	1

Table 6 (cont.)

Upper Columbia Chinook										
Upper Columbia	UCENT	Entiat River	4	9	1	5	5	7	3	1	2
	UCMET	Methow River	5	6	1	6	6	10	6	1	5
		Okanogan River (historic)	10	6	1	6	8	NA	NA	2	4
	UCWEN	Wenatchee River	4	7	1	7	8	7	10	2	5
Lower Columbia Chum											
Lower Columbia	GRAY-CM	Grays & Chinook Rivers	6	10	5	8	5	NA	NA	2	3
	YOUN-CM	Youngs Bay	6	10	5	8	6	NA	NA	2	4
	BIGC-CM	Big Creek	7	10	8	1	6	NA	NA	2	4
	ELOC-CM	Elochoman River	8	10	9	10	7	NA	NA	4	5
	CLAT-CM	Clatskanie River	8	9	7	5	8	NA	NA	3	4
	MILL-CM	Mill Creek	7	10	4	6	10	NA	NA	2	4
	COWL-CM	Cowlitz River	9	10	8	8	9	NA	NA	5	5
	KALA-CM	Kalama River	4	10	5	9	6	NA	NA	2	3
	SCAP-CM	Scappoose River	9	9	8	9	10	NA	NA	5	5
	LEWS-CM	Lewis River	8	10	6	9	9	NA	NA	4	5
	SALM-CM	Salmon Creek	10	8	10	10	10	NA	NA	5	5
	CLCK-CM	Clackamas River	7	8	10	10	10	NA	NA	4	5
	WASH-CM	Washougal River	9	10	6	8	10	NA	NA	4	5
	SAND-CM	Sandy River	8	9	5	8	10	NA	NA	4	4
	LGRG-CM	Lower Gorge Tributaries	5	8	7	8	6	NA	NA	2	4
	UGRG-CM	Upper Gorge Tributaries	6	8	5	9	8	NA	NA	3	4
Snake River Sockeye											
Upper Salmon River	SRRED	Redfish Lake	1	1	NA	NA	3	NA	NA	0	0
	SRRED	Alturas Lake	1	4	NA	NA	4	NA	NA	0	0
	SRRED	Petit Lake	1	2	NA	NA	5	NA	NA	0	0
Middle Columbia Steelhead											
Cascade Eastern Slope Tributaries	MCWSA-s	While Salmon River (historic)	1	9	1	2	7	1	1	1	2
	MCKLI-s	Klickitat River	7	10	2	5	7	1	2	1	3

Table 6 (cont.)

	MCFIF-s	Fifteen Mile Creek (winters)	9	7	4	9	9	3	1	3	4
	DREST-s	Deschutes River, Eastside	7	3	2	6	7	1	2	0	3
	DRWST-s	Deschutes River, Westside	5	5	1	2	5	1	1	0	0
		Crooked River - Above Pelton Dam (historic)	5	5	2	5	6	NA	NA	0	1
	DRUMA-s	Upper Deschutes/Squaw creek - Above Pelton Dam (historic)	6	7	2	5	8	NA	NA	1	3
	MCROC-s	Rock Creek	9	5	1	4	7	1	1	1	2
John Day River	JDLMT-s	John Day River lower mainstem tribs	6	3	3	8	7	5	10	2	4
	JDNFJ-s	North Fork John Day River	5	9	1	4	4	5	10	2	2
	JDMFJ-s	Middle Fork John Day River	7	9	1*	5	4	5	10	2	3
	JDSFJ-s	South Fork John Day River	4	7	4*	5	2	4	2	0	1
	JDUMA-s	John Day upper mainstem	5	8	9*	9	5	8	10	5	5
Umatilla and Walla Walla Rivers	MCUMA-s	Umatilla	10	5	9	9	9	5	10	5	5
	WWMAI-s	Walla Walla River	9	4	10	10	10	10	10	6	6
	WWTOU-s	Touchet River	10	2	10	10	10	6	10	5	6
Yakima River Group	YRTOS-s	Toppenish ans Satus Creeks	7	6	5	5	8	4	2	1	3
	YRNAC-s	Naches River	6	7	3	7	8	7	10	2	6
	YRUMA-s	Yakima River upper mainstem	6	8	4	9	8	9	10	5	6
Snake River Steelhead											
Lower Snake	SNTUC-s	Tucannon River	10	4	5	10	9	4	1	3	3
	SNASO-s	Asotin Creek	10	2	8	10	10	5	10	5	5
Clearwater River	CRLMA-s	Clearwater lower mainstem	10	5	3*	9	10	7	5	3	4
	CRNFC-s	North Fork Clearwater (Historic)	4	8	1*	2	2	5	1	1	1
	CRLOL-s	Lolo Creek	7	9	1*	3	7	4	1	1	3
	CRLOC-s	Lochsa River	1	6	1*	1	3	5	1	0	1
	CRSEL-s	Selway River	1	2	1*	1	1	5	1	0	0
	CRSFC-s	South Fork Clearwater River	4	8	1*	1	2	5	2	1	1
Grande Ronde River	GRLMT-s	Grande Ronde lower mainstem tribs	9	7	1	7	7	4	1	1	4

Table 6 (cont.)

	GRJOS-s	Joseph Creek	8	6	1	3	3	4	1	1	2
	GRWAL-s	Wallowa River	8	5	6	8	8	6	3	3	5
	GRUMA-s	Grande Ronde Upper Mainstem	8	9	9	6	7	8	10	5	7
Salmon River	SRLSR-s	Little Salmon and Rapid Rivers	9	8	4**	7	6	6	4	2	5
	SRCHA-s	Chamberlain Creek	1	3	2*	4	3	4	1	0	0
	SFSEC-s	Secesh River	1	6	1*	3	1	4	1	0	1
	SFMAI-s	South Fork Salmon River	1	4	1*	3	4	4	1	0	0
	SRPAN-s	Panther Creek	1	4	1*	4	1	4	1	0	0
	MFBIG-s	Big, Camas, and Loon Creeks	1	1	1*	3	1	4	1	0	0
	MFUMA-s	Middle Fork Salmon River Upper Mainstem	1	1	1	3	2	4	1	0	0
	SRNFS-s	North Fork Salmon River	1	7	3*	6	4	5	2	0	2
	SRLEM-s	Lemhi River	5	3	6*	8	7	10	4	2	4
	SRPAH-s	Pahsimeroi River	4	2	4**	7	5	7	6	0	3
	SREFS-s	East Fork Salmon River	3	2	4**	6	4	9	4	1	2
	SRUMA-s	Salmon River upper mainstem	1	3	2**	5	5	8	6	1	2
Hells Canyon	SNHCT-s	Snake River Hells Canyon Tributaries	7	3	1*	1	3	4	1	0	1
Imnaha River	IRMAI-s	Imnaha River	8	4	1*	2	2	4	1	1	1
Upper Columbia Steelhead											
Upper Columbia	UCWEN-s	Wenatchee River	4	7	1	7	8	7	10	2	5
	UCENT-s	Entiat River	4	9	1	5	5	7	3	1	2
	UCMET-s	Methow River	5	6	1	6	6	9	7	1	5
	UCOKA-s	Okanogan River	6	3	2	NA	10	10	10	3	4

* Floodplain conversion ratings were calculated from the percent area in 100-year FEMA floodplains converted to human-impacted land uses, except for values with an asterisk (*), for which we did not have complete FEMA floodplain data coverage available; these values were calculated as the percent stream length passing through converted land types as in the riparian analysis. We did not have data for Chinook populations CRLMA and SNHCT; values shown are the values that were calculated for steelhead in these basins. See footnote 3 for a description of NA values.

** Values derived from both FEMA maps and our own analyses were available; a linear method of calculation was used here as FEMA coverage was not complete.

Table 7. Salmon and steelhead populations categorized by degree of impact and population status. In this table, habitat was considered compromised with respect to a particular factor if it fell within the top thirty percent of the distribution of the factor (i.e. in the top three bins, each bin comprising 10% of the range of values for each factor). THIS IS A RELATIVELY STRINGENT DEFINITION OF COMPROMISED. Populations exhibiting relatively less poor population status are those that were impaired with respect to only one or two VSP parameters – these are in bold in the "minimally compromised habitat" column. Populations in italics in the "moderately compromised habitat column are those for which identified impacts are restricted to ONLY instream flow and/or diversion entrainment We did not include any assessment of areas blocked to anadromous salmonids, although we anticipate that we will provide this information in the next version of this paper. Extirpated populations not included in this table.

ESU	**Minimally compromised habitat (no tributary habitat factors identified as impaired)**	**Moderately compromised habitat (1-3 tributary habitat factors identified as impaired)**	**Highly compromised habitat (4-7 tributary habitat factors identified as impaired)**
Snake River spring/summer chinook	Wenaha River Minam River Imnaha River South Fork Salmon River[1] **Secesh River[1]** **Chamberlain Creek** Big Creek Lower Middle Fork Salmon R. **Camas Creek** Loon Creek Upper Middle Fork Salmon R. **Sulphur Creek** Bear Valley Creek Marsh Creek[1] N Fk Salmon River Pahsimeroi River **Yankee Fork[2]**	Asotin Creek Tucannon River Wallowa/Lostine Rivers Upper Grande Ronde River Big Sheep CreekLittle Salmon River Lemhi River *Upper Salmon River (lower mainstem)* *E Fork Salmon River* *Valley Creek* *Upper Salmon River (upper)*	Catherine Creek

[1] See discussion under "ESU and population-specific discussion" for additional information

ESU	Minimally compromised habitat (no tributary habitat factors identified as impaired)	Moderately compromised habitat (1-3 tributary habitat factors identified as impaired)	Highly compromised habitat (4-7 tributary habitat factors identified as impaired)
Upper Columbia spring chinook		Wenatchee River Entiat River *Methow River*	
Snake River steelhead	Lochsa River Selway River Chamberlain Creek Secesh River[4] **South Fork Salmon River**[4] **Big, Camas and Loon Creeks** Middle Fork Salmon, upper mainstem North Fork Salmon River Pahsimeroi River Snake River Hells Canyon tributaries	Tucannon River Clearwater R., lower mainstem Lolo Creek South Fork Clearwater River Grande Ronde, lower mainstem Joseph Creek Wallowa River Little Salmon and Rapid Rivers Lemhi River *East Fork Salmon River* *Salmon River upper mainstem* Imnaha River	Asotin Creek Grande Ronde Upper Mainstem
Upper Columbia steelhead		Wenatchee River Entiat River *Methow River* Okanogan River	

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[1] Panther Creek and the East Fork South Fork both fell in this category on the basis of our analyses. We did not include them, however, due to known historic mining impacts.
[2] Yankee Fork also has substantial mining impacts not accounted for in this analysis.
[4] See text under “ESU and population-specific discussion for further information.

ESU	Minimally compromised habitat (no tributary habitat factors identified as impaired)	Moderately compromised habitat (1-3 tributary habitat factors identified as impaired)	Highly compromised habitat (4-7 tributary habitat factors identified as impaired)
Mid-Columbia steelhead	Deschutes River, Eastside **Deschutes River, Westside** South Fork John Day River	Fifteen Mile Creek Klickitat River Rock Creek John Day, lower mainstem tribs North Fork John Day River Middle Fork John Day River Toppenish and Satus Creeks Naches River	John Day R., upper mainstem Umatilla River Walla Walla River Touchet River Yakima River, upper mainstem
Snake River fall chinook[1]	NA	NA	NA
Snake River sockeye	Redfish Lake		
Columbia River chum		Grays and Chinook Rivers Youngs Bay Big Creek Clatskanie River Mill Creek Kalama River Lower Gorge Tributaries Upper Gorge Tributaries	Elochoman River Cowlitz River Scappoose River Lewis River Salmon Creek Clackamas River Washougal River Sandy River

[1] See text under "ESU and population-specific discussion" for clarification.

Table 8. Salmon and steelhead populations categorized by degree of impact and population status. In this table, habitat was considered compromised with respect to a particular factor if it fell within the top fifty percent of the distribution of the factor (i.e. in the top five bins, each bin comprising 10% of the range of values for each factor). THIS IS A RELATIVELY RELAXED DEFINITION OF COMPROMISED. Populations exhibiting relatively less poor population status are those that were impaired with respect to only one or two VSP parameters – these are in bold in the "minimally compromised habitat" column. Populations in italics in the "moderately compromised habitat" column are those for which identified impacts are restricted to ONLY instream flow and/or diversion entrainment We did not include any assessment of areas blocked to anadromous salmonids, although we anticipate that we will provide this information in the next version of this paper. Extirpated populations not included in this table.

ESU	**Minimally compromised habitat (no tributary habitat factors identified as impaired)**	**Moderately compromised habitat (1-3 tributary habitat factors identified as impaired)**	**Highly compromised habitat (4-7 tributary habitat factors identified as impaired)**
Snake River spring/summer chinook	Wenaha River **Chamberlain Creek** Big Creek Lower Middle Fork Salmon R. **Camas Creek** Loon Creek Upper Middle Fork Salmon R. **Sulphur Creek** Bear Valley Creek Marsh Creek[1]	Tucannon River Minam River Imnaha River Big Sheep Creek South Fork Salmon River[1] Secesh River[1] N Fk Salmon River Lemhi River Pahsimeroi River *E Fork Salmon River* Yankee Fork[2] Valley Creek Upper Salmon River (upper)	Asotin Creek Wallowa/Lostine Rivers Catherine Creek Upper Grande Ronde River Little Salmon River Upper Salmon River (lower mainstem)

[1] Panther Creek and the East Fork South Fork both fell in this category on the basis of our analyses. We did not include them, however, due to known historic mining impacts.
[1] See discussion under "ESU and population-specific discussion" for additional information

[2] Yankee Fork also has substantial mining impacts not accounted for in this analysis.

ESU	Minimally compromised habitat (no tributary habitat factors identified as impaired)	Moderately compromised habitat (1-3 tributary habitat factors identified as impaired)	Highly compromised habitat (4-7 tributary habitat factors identified as impaired)
Upper Columbia spring chinook		Entiat River	Wenatchee River Methow River
Snake River steelhead	Selway River Chamberlain Creek **South Fork Salmon River**[4] **Big, Camas and Loon Creeks** **Middle Fork Salmon, upper mainstem**	Tucannon River Lolo Creek Lochsa River South Fork Clearwater River Joseph Creek Secesh River[4] North Fork Salmon River Pahsimeroi River East Fork Salmon River Salmon River upper mainstem Snake River Hells Canyon tributaries Imnaha River	Asotin Creek Clearwater R., lower mainstem Grande Ronde, lower mainstem Wallowa River Grande Ronde Upper Mainstem Little Salmon and Rapid Rivers Lemhi River
Upper Columbia steelhead		Entiat River	Wenatchee River Methow River Okanogan River

[4] See text under “ESU and population-specific discussion for further information.

ESU	Minimally compromised habitat (no tributary habitat factors identified as impaired)	Moderately compromised habitat (1-3 tributary habitat factors identified as impaired)	Highly compromised habitat (4-7 tributary habitat factors identified as impaired)
Mid-Columbia steelhead	**Deschutes River, Westside**	Klickitat River Rock Creek North Fork John Day River Middle Fork John Day River South Fork John Day River Toppenish and Satus Creeks	Fifteen Mile Creek Deschutes River, Eastside John Day, lower mainstem tribs John Day R., upper mainstem Umatilla River Walla Walla River Touchet River Naches River Yakima River, upper mainstem
Snake River fall chinook[1]	NA	NA	NA
Snake River sockeye	Redfish Lake		

[1] See text under "ESU and population-specific discussion" for clarification.

ESU	Minimally compromised habitat (no tributary habitat factors identified as impaired)	Moderately compromised habitat (1-3 tributary habitat factors identified as impaired)	Highly compromised habitat (4-7 tributary habitat factors identified as impaired)
Columbia River chum		Grays and Chinook Rivers Kalama River	Youngs Bay Big Creek Elochoman River Clatskanie River Mill Creek Cowlitz River Scappoose River Lewis River Salmon Creek Clackamas River Washougal River Sandy River Lower Gorge Tributaries Upper Gorge Tributaries